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If we study, the world over, the causes of fatality following major operations, we find either sepsis or shock at the head of the list. Of recent years there has progressively been a lowering of the mortality due to infection of wounds; but is this true of the proportion of deaths from shock? It has seemed to me that for many years little advance has been made in our method of handling shock. No surgical topic more deserves our research; none receives it so little. An infinite number of minor topics takes up the time of our investigators; but this, the great lion in the road to recovery, is avoided to a degree that is surprising. How can one help feeling astonished at such neglect who observes that even the most recent surgical text-books almost ignore it? For example, in New York State, two prominent works, recently issued, of 1240 and 1600 pages, respectively, devote the one, four, and the other, three pages to the entire topic of shock! The same is true of the largest and most recent London work on surgery, of 2272 pages, which devotes four of them to the greatest cause of surgical deaths (next to infection)—not much more space than is devoted to bunion!

Space precludes a discussion of the pathology of shock, and yet a few sentences are necessary in order to make clear the views upon which at least in part the treatment is based. Doubtless the last word has not yet been written on this topic. Nevertheless, the experiments of Professor Golz of Strassburg[2] have never been successfully contravened. They are well known to all surgeons.

(1) Read at the Ninety-Third Annual Meeting of the Medical Society of the State of New York, held at Albany, January 31st and February 1st and 2nd, 1899. Reprinted from the *Medical News*, Feb. 25th, 1899.

(2) *Virchow's Archives* for 1875. "Ueber den Tonus der Gefässe und Seine Bedeutung für die Blut bewegung."

We may divide our cases of shock into, *first*, those in which the cause, whether a physical or a mental blow at the nervous system, partially abrogates the functions of the sympathetic nervous centers; *second*, where the cause partially abrogates the functions of the cerebro-spinal nervous centers, as well as of the sympathetic.

In the first group the brain does not succumb to the blow. It is still capable of performing its functions fairly well. The sympathetic nerves, however, no longer properly invigorate the cardiac ganglia, and the tone of all the blood-vessels is also lost. Because of the weak heart-action the blood tends to accumulate in the veins. The patient bleeds inwardly, that is, into his own veins. The blood, like any fluid, must move in the direction of least pressure, and so it accumulates in the relaxed, dilated veins, leaving the arteries partially emptied. The condition in its resultant symptoms is identical with internal hemorrhage. I know of no surgeon capable of making a diagnosis between this not very uncommon type of shock and inward bleeding. It is interesting to note that Professor Hare has recently shown that death from chloroform narcosis is really death from shock; his words are: "The man is suddenly bled into his own veins and capillaries as effectively as if into a bowl."

We should note that in this, sometimes called the *erethistic* type of shock (to distinguish it from the commoner *torpid* or *apathetic* type), the victim is usually perfectly conscious until nearly the moment of death; occasionally toward the end, is a little delirious or even convulsive, from cerebral anemia. He is restless, tossing about; he is thirsty, and yet often nauseated; he sighs for more air; his skin is cold, pale and wet; his pulse is rapid and feeble. Are not these, each and all, the signs of inward bleeding? But they are just as truly the signs of the erethistic type of shock. I am personally cognizant of two instances in which a famous gynecologist—a man of great surgical experience—treated a patient *post-operationem* for shock, but the autopsy showed the abdomen to be full of blood, due to a slipped ligature of the stump.

In the one case (shock) the bleeding is *into* the paralyzed and dilated vessels; in the other (hemorrhage) *out* of the vessels. But

the symptoms are one and the same, and are due mainly to lack of blood in the brain and heart.

In the second and commoner type of shock—the *torpid* or *apathetic*—not only the sympathetic system, but also the cerebro-spinal centers, have felt and partly succumbed to the blow. The patient is, in the milder cases, mentally benumbed; in the worst ones, quite unconscious. Because of this benumbing of the higher centers, the signs of this, the commonest type of shock, necessarily differ very much from those of the first type described. He does not suffer, as would an active brain, from dyspnea, nor is he restless, nor does he complain of nausea nor of thirst. He has, however, the cold, pale, sweating skin, the rapid, feeble pulse, the shrunken features, of inward bleeding. Often he has lost control of his sphincters. Sometimes he is a little delirious or convulsive—more commonly, simply in stupor. His symptoms are precisely those of hemorrhage, except as just stated; and the reason for the difference is obvious.

The only condition (save inward hemorrhage and occasionally a form of extreme sepsis) which can be confused with shock is fat embolism, and the differential diagnosis is not difficult. It is a special danger of fractures, and lacerations of, or operations upon, fatty tissues. At first, the lungs suffer most from the infarction; later if the patient survives and the fat is forced on through the pulmonary capillaries, the kidneys and other organs may also undergo fatty embolism. Five points aid in clearing up the diagnosis: (1) The time at which fat embolism develops. This, as compared with shock, is usually late, from two to three days after the injury. (2) The cyanosis, due to plugging of the vessels of the lungs. (3) The extreme dyspnea, with very rapid breathing and sometimes bloody foam or even hemoptysis. (4) The mental excitement which often ushers in the symptoms. (5) The presence of fat in the urine.

Causes of Shock.—These are properly divided into I. *predisposing*, and II. *exciting*.

I. Under the first head, fear is a considerable factor. I know personally of one fatal case in which the subject, shown by an autopsy most carefully made to have no apparent lesion or disease

of any organ, died apparently of sheer cowardice, some hours before the time set for operating upon piles. His agitation and fright rapidly increased, and he suddenly collapsed, dying within an hour, and with symptoms of shock. All measures tending to reassure patients and to calm them are of utmost value in preventing shock. This is one reason why the writer always prescribes whisky and a little morphin with atropin an hour before operation. The patient, otherwise more or less frightened, takes his anesthetic in a calmer, an almost cheerful, frame of mind. Also, as these drugs are analgesics, less ether or chloroform is needed than otherwise, and hence there is less danger from it.

We should not forget, as one peril from *major* operations under *minor* anesthesia, that a conscious patient must be nervously affected in an unfavourable way by hearing the saw grating through his bone, or by seeing the bloody paraphernalia used, etc. All this tends to invite shock. To illustrate, an aspiring needle may safely be introduced in several directions into the brain of a patient who is under general anesthesia; whereas, the same needle would probably cause prompt death from shock if driven into the brain of the same patient while conscious. Furthermore, a conscious patient whose thoughts are diverted elsewhere, at the time of being cut, is apt to feel much less shock than one who is nerved to the suffering he is expecting. It is easier to snap a tense thread than one relaxed. All military surgeons have noted that a soldier severely wounded in battle may not realize it at all, for some time thereafter; and will suffer less from shock than if he were to lie down on the table in a state of expectancy, and while conscious receive an equally grave physical injury.

From the above points it follows that although one may, for example, amputate a thigh painlessly under cocain or other minor anesthesia, it may very possibly result in a greater degree of shock than would have followed general anesthesia.

Under the heading we are discussing comes also impairment of vital energy by uremic or lithemic or diabetic troubles, or other constitutional dyscrasias; by opium or certain other habits; by prolonged sleeplessness; by business worries or other anxieties; by recent illness; or by either infancy or extreme old age. Some-

times, too, there is a family inheritance whereby the slightest operation proves perilous; whereas, on the other hand, we occasionally find a man whom the most scientific surgeon can hardly kill—such is his vital resistance to shock.

II. *Exciting Causes of Shock.*—These may come in the form of either mental or physical blows. We are now discussing the latter, mainly; and regarding operations, there are four of chief importance. These are: (1) Loss of blood; (2) length of operation; (3) excessive major anesthesia; (4) loss of vital heat during operation.

1. As to the first of these four: with advancing years a surgeon has an increasing respect for a drop of blood. Hemorrhage is not the only cause of shock; indeed, one may die from shock produced by a blow on the abdomen, and without any bleeding. Nevertheless, hemorrhage is certainly the main cause. Shock is apt, in its severity, to be directly proportionate to the amount of blood lost.

2. As to the length of the operation, here is a matter too often neglected. In abdominal work, especially, speed is only second to asepsis as the leading factor in success. If the operation lasts an hour or more, in a given case, the patient is apt to "die cured:" whereas, with half the time, or less, the great sympathetic centers do not suffer so terribly from the exposure. The most successful gynecologist I know operates with a speed like a sleight-of-hand trick.

Since the introduction of anesthesia, the really rapid operators have become few; and not all surgeons seem to realize how prejudicial to the patient it is to prolong an operation for the purposes of demonstration to the bystanders. I think it would be well if certain operations of grave peril were more often *parted in the middle*, so to speak. In the enucleation of some great tumour of the neck, for example, which has already taken much time, and promises with the careful dissection needed to occupy as much more, and in which the patient is weak—here let us leave our work unfinished, apply a sterile dressing, and wait two or three days if need be, until he is fit to bear the remainder of the cutting. Of course this is no new idea, but it is much less often adopted in practice than would seem wise.

3. As to excessive depth of major anesthesia, we all know that quite aside from the severity of the accompanying operation, this jeopardizes the patient's chances of escaping shock. Occasionally we see the surgeon permitting his assistant to keep the patient snoring heavily throughout. As a rule this, which is an indication of deep paralysis of the velum palati, is needless, and worse.

4. It invites also the fourth main cause of shock enumerated —loss of vital heat. Prolonged and profound anesthesia, as we all know, results in a heavy fall of bodily temperature. And too often, careless exposure of the subject upon the table adds to this chilling.

Treatment.—It is the chief purpose of this paper to endeavour to emphasize the extreme value of certain means of *preventing* shock which would otherwise develop. Upon this plan of campaign against this great enemy can we alone rely for better figures of mortality than those of the past. If we wait until shock has actually struck its blow, too often that blow proves deadly. Where the gravity of the operation or severe loss of blood or other cause makes shock a probability, let the surgeon use the "ounce of prevention" by *striking first!*

Of course we should endeavour to build up the patient's vital resistance by all means in our power. Where weakness from a constitutional dyscrasia or from any removable cause exists, the indication for a preparatory line of treatment is plain. In most cases it is also well to exhibit strychnin in minute doses for several days before a major operation, thereby invigourating the nervous system. But the chief reliance, the one which is already working wonders in the hands of those who know how to use it, is the free use of intravenous, hot, saline infusion, injected while the patient is still upon the operating-table and asleep from the anesthetic, in cases where the advent of shock, otherwise, seems a probability.

The use of saline solution to treat a patient already collapsed from shock is not a new thing. Neither is it a brilliant success, because nothing is, when severe shock has actually arrived. Some text-books mention it with dubious praise; others almost or

quite ignore it. But the thing which is my own suggestion (so far as a study of the "Index Medicus" and the New York Academy of Medicine Library enables me to judge) is the use of this great weapon for good at the right time, and the right temperature.

This plan for the *prevention* of shock has been in use in my clinic since the autumn of 1891, as a consequence of conclusions reached after several months of experimental work upon dogs, with hot and cold vascular saline infusion after bleeding, testing intra-arterial pressures at differing temperatures of the injected fluid, with the kymograph and the mercurial manometer, under the kind supervision of Professor Curtis in the Columbia University Physiological Laboratory during the winter and spring of 1890–91. So far as I have seen printed evidence, other surgeons did not until later adopt this plan in prevention of shock,[1] and it is commonly ignored even to-day by the bulk of the profession.

In evidence of priority is submitted a brief quotation from the writer's paper read before the Surgical Section of the New York Academy of Medicine, November 9th, 1891, and published in the *Medical Record*, January 2nd, 1892: "Whosoever has noted the vigour with which unstriped muscle everywhere reacts to the use of heat—for example, the much stronger and decidedly more permanent uterine contractions which result from hot post-partal injections as contrasted with cold ones—must believe it probable that such unstriped muscle, forming as it does a most important tunic of the blood-vessels, would be greatly aided by hot saline infusion in regaining its lost tone. Perhaps, too, the central sympathetic centers would feel and respond to this stimulus. Now, since a more vigourous cardiac action (for the heart, though striated muscle, responds to the heat), accompanied by a somewhat restored vascular tone, would go far toward recovery both from hemorrhage and its attendant shock, I have felt that the experiment was well worth trying. (I had tried it as a preventive of shock upon dogs only, before the paper was written.)

Again a quotation from the writer's article in the *Medical Record* for November 12th, 1892: "And why would it not be well

(1) Dr. F. Lange did, however, in 1888, advocate diluted claret by rectum to prevent shock, where a very bloody operation was anticipated; and Drs. Weir, Tiffany and others in the discussion approved of water in this way. ("Trans. Am. Surg. Asso.," vol. IV, p. 540, *et seq*.)

at the end of any and every operation grave enough to make shock a probable result (though, because of the ether, not as yet at hand), to inject subcutaneously (*i. e.*, intravascularly) a quart or two of hot salt water? It would be painless, the patient not yet being out of anesthesia. It would certainly be harmless. And I believe it would do much to prevent, by maintaining filled blood-vessels, otherwise fatal shock from developing. It seems not improbable that we shall ultimately see this done as a matter of routine after all severe operations." At that early date the writer had tried the method in but very few instances to prevent shock, using a half litre or more within the vessel and as much more in the cellular tissues; and could not, of course, speak as all can to-day who have used it properly, with absolute certainty as to its value upon human patients.

In this connection five points deserve especial consideration: (*a*) the place of entrance, (*b*) the proper solution, (*c*) the proper temperature of that solution, (*d*) the proper amount, and (*e*) the speed of introduction.

(*a*) In most cases the median basilic vein is chosen for the cannula. Occasionally a vein in the operating wound will do. The writer demonstrated some years ago that if one is caught short of tools—has no scalpel, no cannula, no dissecting forceps nor retractors at hand—the saline infusion can safely be made to enter the common femoral artery (which, being large enough to admit a lead pencil, can always be felt pulsating if the patient still lives) by aid of a hypodermic needle attached to a Davidson syringe or a fountain syringe.[1]

We must not neglect to mention that when speed is not a factor—when a prompter stimulant effect is not essential—the rectal route is an excellent one. Even during the operation the maintenance of a full large bowel by means of Kemp's rectal irrigator can only be of benefit, and is additionally a means of safeguard against dangerous chloroform narcosis—by maintaining filled vessels. And after the patient is removed to bed it is sometimes wise (in order to continue the good effects of the intravas-

(1) For details, again discussed, as to this emergency method see *Medical Record*, December 10th, 1898.

cular infusion until the danger-point is well past) in bad cases to give the hot colonic irrigation alternately, an hour on and an hour off, for perhaps a half day.

When, following confinement, the accoucheur has a partly exsanguinated patient, he adds wonderfully to her comfort if he injects high up a couple of litres or more of very hot salt water by rectum. It is instructive to note that not a drop of the amount thus poured into the colon will ever be seen again. It is taken up greedily by the thirsty blood. In an emergency, elevating the foot of the bed upon a high chair, and pouring in the salt water through an ordinary tin funnel inserted in the anus, suffices. If the loss of blood has been extreme, intravascular infusion should also be employed; for the condition of the bowel-wall, and of the refuse material coating it, may, at times, have an adverse effect upon ready exosmosis of the salt water from the intestine, rendering this route perhaps less trustworthy.

As to hypodermoclysis, it is the slowest of all methods. The lymphatics are not very speedy in permitting the diffusion of water entering the connective tissues. Also, if the proper bulk of fluid is so introduced, it means quite a number of punctures, painful the next day. To prevent shock, then, I advocate other routes in preference to this. Upon its special value at times in choleraic infant diarrhea I have heretofore written.[1]

(*b*) The fluid used should be the so-called normal, really decinormal, salt solution, which is six parts of common table salt per thousand, boiled and filtered; roughly a heaped teaspoonful to the litre or quart. So far as we are able to observe, this is as good, practically, as more complicated formulæ resembling more closely the exact chemical composition of the blood-serum. The use of *blood* transfusion, both for treating post-hemorrhagic conditions and shock, has been entirely dropped, as no more effective at the moment than saline infusion, and as being dangerous, later, both from possible embolism, and from the certainty that every blood-cell so introduced will speedily break down, threatening to clog the liver and kidneys with the waste products of destructive or retrograde metabolism of tissues.

(1) *Medical Record*, November 12th, 1892; also December 10th, 1898.

It does not seem so widely known as should be the case that plain, warm water, devoid of sodium chlorid, must not be used intravascularly. For example, in a recent article, in the *Medical Record*, [1] upon "Saline Infusion," the author, Dr. Reilly, copies without adverse comment a most dangerous bit of advice from Messrs. Bosc and Vedel; namely, that "ordinary water is non-toxic, not very destructive to the red corpuscles, and might be used in an emergency." Also, in the "Transactions of the London Obstetrical Society" (meeting of December 6th, 1893), may be seen a similar suggestion by a member, Dr. Horrocks, who was of opinion that the salt was a luxury, but not a necessity. He did not claim, however, actually to have ever used plain water in this way, and no member present agreed with him in advising it. It is certain that whosoever tries this, will, if the water be used in the customary large amount, kill his patient with quite indecorous speed by a wholesale disintegration of the red discs. The addition, however, of even so small a proportion of salt as six tenths of one per cent. renders it safe for vascular infusion. Perhaps a quotation from an experiment of mine at the Columbia University Physiological Laboratory may emphasize this point, which surely needs emphasis.[2] "On May 15th, 1891, I operated on a large dog, weighing before operating 16.77 kilos. On the one-in-thirteen hypothesis (of blood to body weight) his weight of blood would have been 1290 grams, or, allowing for the specific gravity of blood, about 1222.75 c. c. The cannula of the mercurial manometer was introduced into the right carotid. The right femoral was used for bleeding, the left femoral for injection of the hot salt solution. Professor Curtis superintended the working of the kymographic needle. Dr. F. J. Brockway assisted me. We drew 563 c. c. of blood."

Upon attempting to replace this, and a smaller subsequent bleeding, by the salt solution, with which at various temperatures I was experimenting, a mistake – a most interesting and instructive one—was made. "Dr. Brockway and I each supposed that the other had added the salt to the hot water, whereas, in fact,

(1) *Medical Record*, November 12th, 1898.
(2) See *Medical Record*, January 2nd, 1892.

neither had done so. And within a minute after receiving a considerable amount of this plain-water injection the animal died." Previous dogs, bled to an equal degree, had done beautifully and recovered under saline infusion. Hence, we were much puzzled until Professor Curtis asked if the salt had been added, and stated that without it water in considerable amount will kill almost as quickly as prussic acid—and in the way already named.

(*c*) The proper temperature for the injection fluid is *as hot as the hand can bear*, and this is about 120° F. or 49° C. (Of course the temperature at the heart, when the great bulk of blood has diluted the slowly entering fluid, will be much lower than this.) There need be no fear of injuring the blood or other tissue by such heat. Very many times the writer has now used it, and never with cause for subsequent regret. This point seems not at all well known as yet in the profession, and nearly all the text-books still advise infusion at about 100° F. The higher temperature here recommended is very stimulating to the flagging heart, and maintains the tone of the muscular tunic of the vessels. This is well illustrated in the photographs I now show you of kymographic carotid tracings at various temperatures. So recently as last winter Dr. Robert Coleman Kemp, at the Columbia Physiological Laboratory, in pursuing some investigations in a somewhat different line, had occasion to repeat my manometric and kymographic experiments of some seven or eight years ago, and re-verified their correctness—he, too, finding that at 118°–120° F. the tracings showed the best results upon heart and vessels. His statements were published in the *Record* early last autumn.

To maintain the desirable degree of heat, the reservoir containing the water should be wrapped in a large towel or sterile blanket during the time occupied by the act of infusion.

In Dr. Reilly's article, quoted, he mentions a conclusion of Athansin, a French experimenter, upon this matter of the proper heat, which I must believe to be an error. He says: "In animals, at least, solutions having a temperature of 165° to 175° F. can be safely used." Now, upon reference to Kirke's "Physiology," eleventh edition, p. 846, it will be seen that globulin coagulates

at 70° C. (158° F.), and Dalton's "Physiology," seventh edition, p. 80, affirms that serum-albumin clots at 72° C. (162° F.)

It will be noted, however, that both 158° F. and 162° F. are about 40° F. hotter than the hand can support, as above stated. So that the temperature which I advise is a long way from being unsafe. The hand-test of the heat, as suggested, will be found both safe and accurate enough in actual practice.

(*d*) The proper amount of the injection fluid may be set down, for the adult, as never less than a litre, often two litres, and occasionally, perhaps even three litres, injecting always very slowly. To give a half-litre or less is, for the prevention of shock, almost valueless. The limit of safety as to large quantities has not as yet been very exactly formulated. The kidneys readily remove any water from the blood in excess of its needs. Should these be diseased, a less amount must of course be employed than otherwise.

(*e*) The time occupied in introducing the fluid into a vein should never be less than ten minutes per litre. To be sure, I have seen it caused to flow with double this speed and without ill effect; but, on the other hand, a temporary period of threatening heart-failure due to this cause—a rapid overstimulation—has been at times observed.

Of late we have all noticed in the journals that a few enthusiastic friends of this plan of preventing shock by saline infusion are using it at the *beginning* of the operation—before even a drop of blood has been lost, or any strain whatever put upon the nerve-centers. If this were only done by the plan of keeping the large bowel full of hot salt-water, I should find no fault, for here the blood will to some extent take up water only as it needs it. But I doubt the wisdom of the preliminary distention of vessels by intravenous infusion; for one reason, because it is plain that by such a practice we add to the amount of blood lost. For every spurting point will, from increased pressure, spurt much more vigourously before it can be caught, than otherwise it would do.

Just a word as to the repetition of the dose. Many times I have read of surgeons using it once in a given case and reporting a temporary good effect, but that subsequently the patient died of shock. Now, of course no method can save all cases of every

dangerous disease; but common sense would teach us that if a dose obviously does good it should be repeated, and this so long as the same indications call for it. From this it does not follow that we must open a vein again and again. The rectal hot saline douche will, if rightly used, give approximately as good results for such purposes. The bed should always have its foot elevated very high, and this should remain so until danger of shock is well past. This position maintains a better supply of blood to both brain and heart, and also helps in the retention of the fluid in the large bowel. Alternately an hour on and an hour off seems to produce more desirable results than a steady maintenance of the flow through Kemp's tube. I think it wise not to consider the patient past his danger until the pulse becomes as low, at least, as 120 per minute, and shows no tendency to occasional increase above this number.

Thus far I have discussed the *prevention* of shock, but have said nothing as to its treatment when actually developed and threatening the patient's life. Concerning this last I have little to say, and that is not new. If we are unfortunately called to an accident case and find the victim in collapse, which is another name for shock, hot saline infusion is worth trying—but with small hope. Strychnin hypodermically is probably, when used freely, our best reliance. Some surgeons use it even to the point of producing slight spasms—if the shock does not yield earlier. Hot applications about the person are essential—elevation of the foot of the bed, a help. But two prominent "*don'ts*" should never be forgotten, namely, *don't* over-stimulate the heart, and *don't* give a particle of food by mouth, nor any medicine even remotely capable of causing nausea.

If the pulse come down to anything like reasonably safe numbers—as discussed a minute ago—let well enough alone; for if that tired heart be over-whipped it is likely to quit work. And as for the second "*don't*," what is nausea in all of its symptoms but one type of shock? There is the cold, wet skin, the weak pulse, the sensation of vital collapse; and no one should take the least risk of adding this—if not already present—to the surgical shock.

The duration of shock is not many hours, as a rule—as to its worse phase. Certainly it is not so prolonged but that the patient may easily have his strength sustained during this period, without using his stomach—by nutrient enemata, or hot coffee by rectum, etc. And any needful remedies which might otherwise possibly nauseate can surely also be administered by this route, or better still, by needle. I dwell upon this matter, because one so regularly sees this "*don't*" neglected, to the patient's detriment.

I wish that time permitted a discussion of the question of amputation of crushed and lacerated limbs during shock, and of the relation of anesthesia to this question, but this is impossible.